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European Patent Office
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(19)

(11) Publication number: 0 543 430 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 92203122.4

(22) Date of filing: 09.10.92

(30) Priority: 20.11.91 US 795866

(43) Date of publication of application: 26.05.93 Bulletin 93/21

(84) Designated Contracting States: DE FR GB IT

(51) Int. Cl.5: G01L 9/00

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(54) Pressure sensor and method of assembly thereof.

(57) A pressure sensor assembly is provided containing a substrate (116) having signal conditioning circuitry (110,126,130) disposed on both surfaces (134,136) of the substrate (116), with the critical pressure sensing element (140) disposed on one surface (134) of the substrate (116) and the laser trimmable resistors (120) disposed on the other surface (136) of the substrate (116). A ported housing (118) seals the one side (134) of the substrate (116) containing the pressure sensing element (140), thereby forming a pressurizable chamber while having the signal conditioning circuitry (126,130) and resistors (120) on the other surface (136) exposed for calibration by laser trimming of the resistors (120). This eliminates the requirement for a separate housing for the critical pressure sensing element (140). In addition, when the ported housing (118) is mounted to the pressure sensing side (134) of the substrate (116) for formation of the sealed pressure chamber, the through-holes (122) which electrically interconnect the signal processing circuitry (110,126,130) on both sides (134,136) of the substrate (116) are also concurrently sealed.

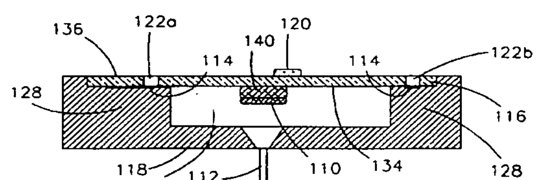

FIG.6

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This invention relates to a pressure sensor and to a method of producing a pressure sensor. More particularly, an embodiment of this invention relates to the packaging and assembly of a pressure sensor, wherein the sensor employs a double sided substrate having thick film circuitry on both surfaces, as well as an enclosed pressure sensitive integrated circuit on one of those surfaces, yet exposed signal conditioning circuitry on the other surface allowing for calibration of that signal conditioning circuitry by laser trimming means.

Pressure sensors are used in automotive vehicles for a variety of purposes, such as for sensing the vacuum pressure at the intake manifold of a vehicle's engine, as well as for other applications. Generally, such pressure sensors contain a pressure sensitive element. A common type of pressure sensitive element includes a piezo-resistive silicon element which is integrated with appropriate adjusting circuitry in a monolithic silicon integrated circuit. The piezo-resistive silicon element typically contains a diaphragm and piezo-resistive strain sensors disposed on the diaphragm, which are connected to the adjusting circuitry for measuring the deflection of the diaphragm due to pressure changes.

Often, the pressure sensor requires calibration to compensate for the variations that tend to occur during manufacturing between individual pressure sensing elements and signal conditioning circuitry. To provide for this compensation, it is advantageous to include either separately or as part of the integrated circuit, a conditioning network that permits customized adjustment of the output parameters for the individual pressure sensor. This conditioning network typically is a network of resistors, of which some may be selectively modified or removed from the integrated circuit by laser trimming the area of the resistors or alternatively by opening fusible links in the network. However, in order to calibrate these pressure sensors, the critical pressure sensing element must first be enclosed within a pressurizable chamber.

In the past, many different types of pressure sensor assemblies have been disclosed. Often, the pressure sensing element has been disposed within a separate container for pressurization by means of a port, such as disclosed in US-A-4,295,117. The separate container allows the pressure sensing element to be appropriately pressurized while the signal conditioning circuitry remains exposed, thereby facilitating the laser trimming of the exposed circuitry during calibration. An illustrative example of this type of prior art pressure sensor assembly is illustrated in cross-section in Figure 1. (The size of the components shown in Figures 1 to 3 are enlarged for the purposes of this description.) The container 10 housing the pressure sensing integrated circuit is located adjacent to, but separate from, the substrate 16 having the associated signal conditioning circuitry. The container 10 is required so that the pressure sensing element can be pressurized. Both the container 10 and substrate 16 are glued to a backplate 14, therefore leaving only one side of the substrate 16 available for the signal conditioning circuitry. This is an inefficient use of substrate space and unduly increases the size of the assembly. During calibration of this type of sensor, pressure is applied to the pressure sensing element within the container 10 through a port 12. A laser is then able to access, from above, and trim the resistor 20 within the signal conditioning circuitry, before a cover 18 is attached.

This prior art approach of Figure 1 has generally been satisfactory, although has shortcomings. The separate container 10 housing the sensing element undesirably increases the number of components within the assembly. The use of a separate container 10 also requires that additional interface joints be formed within the assembly, which increases the number of processing steps, thereby possibly decreasing product reliability. Also, as stated above, by utilizing only a single side of the substrate 16 for the signal conditioning circuitry, the available area of the substrate is not efficiently maximized.

An alternative prior art approach is shown in cross-section in Figure 2. In this configuration, the critical pressure sensing element 10a is attached to a substrate 16 having the associated signal conditioning circuitry also disposed thereon. The substrate 16 is attached to a backplate 14. The pressure sensing element 10a is not contained within a separate container. Rather, pressurization of only the rear of the pressure sensing element 10a is achieved by means of the port 12. In this embodiment, thus, the sensing of pressure changes at the rear of the sensing element is needed for calibration of a resistor 20 within the signal processing circuitry. After laser trimming, a cover 18 is attached to seal and protect the components.

This second approach is problematic in that, again, only a single side of the substrate 16 can support signal conditioning circuitry, since the second side is necessarily sealed by the backplate 14 for pressurization during calibration of the pressure sensing element 10a through the port 12. Therefore, the second side cannot be exposed to the laser trimming operations, leaving only the topside available for the signal conditioning circuitry. In addition, rear sensing technology is required.

Another illustrative prior art approach is shown in cross-section in Figure 3. Here, the substrate 16 is suspended within a housing 18, therefore

permitting both sides of the substrate 16 to support signal conditioning circuitry. However, in order to calibrate the resistors 20a and 20b of the signal conditioning circuitry, the resistors 20a and 20b must be exposed. This, therefore, requires that the pressure sensing integrated circuit be enclosed within its own container 10 and pressurized by means of the port 12, since the sealing cover 18 is not attached until after the laser trimming operations carried out during calibration. Although this approach allows both sides of the substrate 16 to support signal conditioning circuitry, the design is still less than ideal since the pressure sensing element requires a separate pressurizable container 10. In addition, a design such as this would most probably include electrically conductive through-holes for electrical interconnection of the two sides of signal conditioning circuitry. For calibration, these through-holes would also require sealing, unless the pressure sensing integrated circuit was sealed in its own container, as shown.

US-A-4,756,193 and US-A-4,859,227 have offered an alternative approach to housing the pressure sensing element within a separate container. Both these patents leave the pressure sensing chip in an open chamber and then enclose it by means of a flange on the pressure application nozzle. Therefore, when the chamber requires pressurization, such as for the calibration operation, the pressure sensing element is sealed by the flange of the pressure application nozzle. This has been a satisfactory approach; however, this design utilizes only a single side of the device for supporting the signal conditioning circuitry.

The present invention seeks to provide an improved pressure sensor and method of producing such a pressure sensor.

According to an aspect of the present invention, there is provided a pressure sensor as specified in claim 1.

This invention can provide a pressure sensor assembly which maximizes the efficiency of the design by employing a double sided substrate for population by signal conditioning circuitry, and by eliminating the requirement for separately containing the pressure sensitive element. In addition, such a pressure sensor could facilitate the calibration of the signal conditioning circuitry of the pressure sensing element by laser trimming operations. Furthermore, such a pressure sensor can be amenable for manufacturing by automotive production techniques for use in automotive applications.

The invention can also provide a pressure sensor wherein the pressure sensing element is attached to one surface of a substrate, that surface being appropriately sealed and pressurized, yet wherein signal conditioning circuitry including trimmable resistors, remains accessible for laser trimming during calibration, prior to final sealing of the pressure sensor.

Through-holes may be provided from one surface of the substrate to another at a perimeter of the substrate, allowing adhesive at the perimeter of the substrate to seal the through-holes.

According to another aspect of the present invention, there is provided a method of producing a pressure sensor as specified in claim 5.

Preferably, the method concurrently mounts the substrate to a housing and seals through-holes which provide electrical interconnection between the two sides of the substrate having disposed thereon signal conditioning circuitry.

In a practical embodiment, a pressure sensor assembly is provided which provides a substrate having signal conditioning circuitry disposed on opposite surfaces of a supporting substrate, with the pressure sensing element disposed on one of these surfaces and laser trimmable resistors disposed on the other surface of the substrate. A separate housing for the pressure sensing element is not required, since the preferred housing seals the side of the substrate containing the pressure sensing element thereby forming a pressurizable chamber, yet with the preferred housing, the resistors disposed on the opposite side of the substrate remain exposed for laser trimming during calibration.

Preferably, the housing includes a circumferential ledge, on which the supporting substrate rests. This ledge spaces the substrate up from the bottom surface of the housing, thereby forming an air-tight chamber below the substrate for the pressure sensing element. A port may be provided into the chamber within a wall of the housing for pressurization of the chamber. In addition, when the substrate is attached to the circumferential ledge of the housing for sealing the pressure sensing element, through-holes which electrically interconnect the signal processing circuitry on both of the substrates are also concurrently sealed, since the through-holes are preferentially disposed along the perimeter of the substrate so as to contact the circumferential ledge within the housing.

When the substrate is mounted to the circumferential ledge within the housing, the through-holes are preferably sealed and a pressure chamber is concurrently formed. After final calibration and laser trimming of the resistors provided on the opposite surface of the substrate, a cover may be attached to seal the exposed signal conditioning circuitry.

A significant advantage of this embodiment is that the signal-processing circuitry remains accessible until the final passivation treatment is ap-

plied to the assembly. Where thick film circuitry is utilized, such an advantage allows for final trimming of the resistors in the circuit for the purpose of correcting any signal output errors resulting from processing tolerances of the circuit and the pressure sensing element. In addition, the design of this assembly can efficiently provide for opposite surfaces of the supporting substrate to be populated by signal conditioning circuitry, therefore reducing the size of the substrate required and accordingly the size of the entire device. Also, a separate housing for the critical pressure sensing element may not be required since the pressure sensing side of the substrate can be sealed airtight while the other side of the substrate remains exposed for calibration, thereby minimizing the number of components and joints within the assembly. In addition, extra processing steps may not be required for sealing the electrical interconnection through-holes electrically connecting the circuitry disposed on both surfaces of the substrate.

The design of this embodiment can provide a small compact assembly amenable to automotive production techniques.

An embodiment of the present invention is described below, by way of illustration only, with reference to the accompanying drawings, in which:

Figures 1 to 3 are cross-sectional side views of the construction and arrangement of prior art pressure sensor assemblies;

Figure 4 is a cross-sectional bottom plan view of an embodiment of pressure sensor assembly showing a pressure sensing element and associated signal processing circuitry;

Figure 5 is a cross-sectional plan view of the pressure sensor assembly of Figure 4;

Figure 6 is a cross-sectional side view of the pressure sensor assembly taken along line 6-6 of Figure 4 showing a pressure chamber and sealed substrate; and

Figure 7 is a cross-sectional side view of the finished pressure sensor assembly of Figure 6.

As shown in Figures 4 to 7 (which are enlarged views), a pressure sensor assembly is provided which contains a substrate 116 having signal conditioning circuitry disposed on opposite surfaces 134 and 136 of the substrate 116, with the critical pressure sensing integrated circuit 110 disposed on the lower surface 134 of the substrate 116 and signal conditioning circuitry containing at least one resistor 120 disposed on the top surface 136 of the substrate 116 which can be laser trimmed during calibration. The housing 118 seals the bottom side 134 of the substrate 116 containing the pressure sensing chip 110, thereby forming a pressurizable chamber 138, while keeping the resistor 120 on the top surface 136 exposed for subsequent laser trimming. In addition, when the lower surface 134 of the substrate 116 is secured to a circumferential ledge 128 of the housing 118 for formation of the pressure chamber 138, the through-holes 122 which electrically interconnect the circuitry provided on the two surfaces 134 and 136 are sealed at the same time.

With specific reference to Figure 4, a pressure sensing chip 110 is disposed on the lower surface 134 of an alumina substrate 116. The pressure sensing chip 110 preferably consists of a piezo-resistive silicon element which is integrated with adjusting circuitry in a monolithic silicon integrated circuit. The piezo-resistive silicon element typically contains a diaphragm and piezo-resistive strain sensors disposed on the diaphragm and connected to the adjusting circuitry for measuring the deflection of the diaphragm arising from pressure differentials across the diaphragm. Any other suitable means for sensing pressure changes could be employed instead of this type of pressure sensing integrated circuit 110.

The pressure sensing circuit 110 is bonded to the top of a rectangle (or other shape corresponding to the lower surface of pressure sensing circuit 110) of Pyrex (TM) glass or suitable material. A layer of a suitable bonding agent is deposited evenly onto the bottom surface 134 of the substrate 116 at that region where the sensing element 110 is to be attached. The bonding agent ensures uniform adhesion between the components. A preferred bonding agent might be a silicone adhesive, such as Dow Corning 6611 silicone compound. This compound is a high purity silicone having an additional advantage of avoiding ionic contamination of the sensitive electronic circuitry.

The base of the glass layer is attached to the lower surface 134 of the substrate 116 by means of a suitable bonding agent, such as silicone adhesive. The glass layer provides an even transition between coefficients of thermal expansion for the various materials, while the silicone adhesive serves to absorb any undesirable stresses produced during use which could be transmitted directly to the sensing chip 110 if it were mounted directly to the substrate 116.

Additional associated thick film signal processing circuitry, represented by electrically conductive runners 126, is deposited on the lower surface 134 of substrate 116 and electrically connected to pressure sensing integrated circuit 110. The pattern of the runners 126 is merely an example, the actual pattern depending on the specific application for the pressure sensor.

The thick film signal conditioning circuitry represented by runners 126 on the lower surface 134 are in electrical communication with the thick film signal conditioning circuitry provided on the top

surface 136 of the substrate 116 by means of through-holes 122, represented by electrically conductive runners 130 in Figure 5. The electrically conductive runners 126 and 130 allow the input power and output signal to be transmitted to and from the pressure sensor chip 110 for signal conditioning and processing. The conditioned output signal is thereafter transmitted from the thick film circuitry 126 and 130 to the associated vehicle control system by means of external electrical connections (not shown), which are known in the art.

The thick film circuitry 126 and 130 is deposited onto the respective surfaces 134 and 136 of the alumina substrate 116 using conventional means such as silk screening techniques, although other techniques could also be used. The thick film circuitry 126 and 130 can be of any electrically conductive material, such as copper, nickel, palladium or silver or an electrically conductive alloy of these materials. A preferred composition for the thick film circuitry 126 and 130 is a conventional palladium-silver alloy due to its good conductivity and the expertise already available in the field of depositing such a material.

As stated above, electrically conductive through-holes 122a and 122b (shown in Figures 4 and 5) provide connection paths between the two surfaces 134 and 136 of the substrate 116 for electrically connecting the thick film circuitry 126 and 130 on both surfaces 134 and 136 of the substrate 116. The interior, cylindrical surface of the electrically conductive through-holes 122 is coated with an electrically conductive material, such as a conventional palladium-silver alloy, but may include any of those materials listed above for formation of the thick film circuitry. The actual number of through-holes 122 may vary depending on the specific application. Two through-holes 122a and 122b are shown in the embodiment, although it is reasonable to expect that there could be a large number of through-holes in a particular application.

The through-holes 122a and 122b contact respective bond pads 124a and 124b on the lower surface 134 of the substrate 116 (Figure 4) and respective bond pads 124c and 124d on the top surface 136 (Figure 5). The bond pads 124 are formed from the same electrically conductive material as the thick film circuitry 126, so as to ensure intimate and continuous contact between a bond pad 124 and a through-hole 122. Although the bond pads 124 do not need to be formed of the same electrically conductive material used for the thick film circuitry 126 and 130, it is practical and efficient to use the same material on a single surface of the substrate 116 so as to minimize processing steps. The uniform and continuous contact between the through-holes 122 and bond pads 124 ensures continuous electrical connection between the thick film signal conditioning circuits 126 and 130 provided on both surfaces 134 and 136 of the substrate 116.

An advantage of this embodiment is that both surfaces 134 and 136 of the substrate 116 are designed to support signal conditioning thick film circuitry 126 and 130. This preferred design minimizes the space required for the signal conditioning circuitry 126 and 130, thereby providing an efficient and compact pressure sensor package.

As shown most clearly in Figures 4 and 5, the through-holes 122 are purposely positioned along the perimeter of the substrate 116. This readily enables the subsequent sealing and packaging of the pressure sensing integrated circuit 110, as described more fully below. In the preferred embodiment, regardless of the number of through-holes 122 employed, the through-holes 122 are all positioned along the perimeter of the substrate 116. In addition, it is to be noted that the through-holes 122 may be useful for electromagnetic interference purposes as well as for electrically interconnecting the signal conditioning circuitry 126 and 130. For electromagnetic protection, some or all of the through-holes 122 would contact an electrical ground instead of contacting the bond pads 124 associated with the signal conditioning circuitry 126 and 130.

Figure 5 illustrates the top surface 136 of the substrate 116. A single resistor 120 is shown as part of the signal conditioning circuitry 130, although in practice, a plurality of resistors may be provided within the signal conditioning circuitry 130. In addition, although not shown in Figure 4, resistors may be provided on the opposite, lower surface 124 of the substrate 130 as well. However, these resistors would not be accessible by laser trimming methods during calibration. In addition, as stated above with reference to Figure 4, the exact pattern delineated by the thick film circuitry 130 is dependent on the particular application, as will be apparent to the person skilled in the art. The resistor 120 is preferably of a ruthenium thick film material deposited onto the surface 136 using conventional means such as silk screening.

As shown in Figure 6, the lower surface 134, which forms a pressure sensing side of substrate 116, is enclosed within a ported housing 118. The ported housing 118 is preferably formed from a rigid light-weight material, such as Celanex 3300D, a 30% glass filled polyester commonly referred to throughout the industry as "PBT", although other suitable materials could also be employed.

The ported housing 118 contains an integral circumferential ledge 128 disposed around its cir-

cumference for concurrently sealing the through-holes 122 on formation of the pressure chamber 138. The pressure sensing integrated circuit 110 must be in a sealed pressure chamber 138 in order to calibrate the sensor and to operate properly. The perimeter of the lower surface 134 of the substrate 116 is secured to the circumferential ledge 128 of the housing 118 by suitable means, such as Dow Corning 6611 silicone adhesive, although other suitable materials could also be used. This adhesive region is represented by region 114 on the lower surface 134 of the substrate 116 (also shown in Figure 4).

The through-holes 122, which electrically interconnect the signal processing circuitry 126 and 130 on both surfaces 134 and 136 around the perimeter of the substrate 116, also contact the circumferential ledge 128 of the ported housing 118 so as to be sealed concurrently on formation of the pressure chamber 138. This concurrent sealing of the through-holes 122 ensures an air-tight pressure chamber 138 for the pressure sensing chip 110 and intimate adhesion between the ported housing 118 and the substrate 116.

A port 112 is provided within the ported housing 118 for pressurizing the pressure sensing chamber 138. The pressure sensing chamber 138, which encloses the pressure sensing integrated circuit 110, is found by the walls of the ported 118 and the bottom surface 134 of the substrate 116. The port 112 is preferably formed from a rigid molded plastics material, although can be formed from any suitable material that can withstand pressurization. In addition, it may be desirable to provide a plurality of ports 112 within the ported housing 118, depending on the application.

It is to be noted that the pressure sensing integrated circuit 110 can be located anywhere on the lower surface 134 of the substrate 116. It is advantageous that the pressure sensing chip 110 be placed near the centre of the substrate 116 for minimization of stress due to the movement of the diaphragm. However, at this location the chip 110 is the most exposed to the effects of pressurization from the port 112, which can cause other types of stresses. Therefore, in some circumstances it may be preferable to position the pressure sensing chip 110 near but not at the centre of the substrate 116.

During testing and calibration of the assembly, test pressures are applied through port 112 into the pressure sensing chamber 138 over a variety of temperatures. The signal conditioning circuitry 126 and 130 and resistor 120 on the top surface 136 of the substrate 116 are accordingly tested. If modification of the resistor 120 is required, a laser is used to trim the necessary area from the resistor 120, therefore adjusting its resistivity and its signal output. The use of laser trimming is known in the microelectronics art and so will not be described in further detail herein.

It is to be recognized that this embodiment permits testing and adjusting to be carried out without requiring that the entire package, probes or test equipment be enclosed in any special low pressure atmosphere. Moreover, testing and adjusting does not require sensing of the rear surface of the substrate 116 or optical access to the surface of the pressure sensing chip 110.

After testing and calibration, a high temperature vulcanizing silicone passivation gel (not shown), such as Dow Corning Q3-6635, is fed into the chamber to protect the substrate 116 and overlaying circuitry 130 and components 120. Such a protective gel is very compliant for purposes of minimizing stresses due to thermal expansion and contraction of the gel in relation to the internal components of the pressure sensor assembly.

As shown in Figure 7, a top cover 132 is attached to the perimeter of the ported housing 118 to seal the exposed top surface 136 of the substrate 116 having the signal conditioning circuitry 130 and laser trimmed resistor 120. The top cover 132 is preferably formed from a rigid molded plastics material, such as the glass filled polyester employed to form the ported housing 118, or any suitable material. The top cover 132 is attached to the ported housing 118 by any suitable means, such as by the use of an adhesive like Dow Corning 6611 silicone compound.

An air gap of approximately 1.5 mm (1/16 inches) is left between the cover and the silicone passivation gel to provide for thermal expansion.

A significant advantage of this embodiment is that both the pressure sensing integrated circuit 110 and the hybrid thick film circuitry 126 and 130 are enclosed within a package in a manner which minimizes the weight and space requirements of the package. This is accomplished by efficiently utilizing both sides of the substrate 116 for supporting the circuitry. Furthermore, the pressure sensing integrated circuit 110 does not require a separate housing since the pressure sensing side of the substrate 116 is sealed air-tight by the ported housing 118.

An additional advantage is that the through-holes 122 are sealed concurrently as the substrate 116 is mounted to the housing 118, therefore eliminating additional processing steps. This is accomplished with the use of the preferred ported housing 118 which has a circumferential ledge 128 on which the supporting substrate 116 is mounted, which also seals the through-holes 122. This ledge 128 spaces the substrate 116 above the lower surface of the housing 116, thereby forming an air-tight pressure chamber 138 below the substrate 116 for the pressure sensing chip 110.

A further advantage is that the hybrid thick film circuitry remains accessible after being deposited onto the substrate 116 until the final passivation treatment is applied. This allows for final trimming of the resistors 120 in the circuitry 130 for the purpose of correcting any signal output errors resulting from processing of the individual elements of both the circuitry 130 and the pressure sensing integrated circuit 110 due to tolerances and thermally or mechanically induced stresses.

This design provides a small compact assembly which is amenable to automotive production techniques.

The ported housing could also be designed in such a manner as to form a pressure chamber at the same time as sealing the through-holes, even when the through-holes are not located along the perimeter of the substrate.

Claims

1. A pressure sensor comprising a substrate (116) including substantially oppositely disposed first and second surfaces (134,136); thick film signal conditioning circuitry (126,130) disposed on the first surface (134) and including at least one resistor (120) having a resistance adjustable in response to a signal output by the signal conditioning circuitry; a pressure sensing integrated circuit (110) disposed on the second surface and including a pressure sensitive element (140) and associated circuitry (110) for producing a pressure sensitive output signal; at least one electrically conductive passage (122a,122b) in the substrate coupled to the thick film signal conditioning circuitry and to the associated circuitry; and a ported housing (118) including a ledge (128), the substrate being mounted on the ledge and the or each passage being sealed so as to form a pressurized chamber enclosing the pressure sensing integrated circuit.

2. A pressure sensor according to claim 1, wherein the or each electrically conductive passage is located adjacent a perimeter of the substrate; the ledge of the ported housing extending along the perimeter of the substrate.

3. A pressure sensor according to claim 1 or 2, comprising a cover (32) for enclosing the first surface (136) of the substrate after adjustment of the resistance of the or each resistor disposed on the first surface of the substrate.

4. A pressure sensor according to any one of claims 1 to 3, wherein the substrate is of alumina and the pressure sensing integrated circuit is of silicon.

5. A method of producing a pressure sensor comprising the steps of providing a substrate (116) including first and second surfaces (134,136); providing on the first surface (136) a thick film signal conditioning circuit (126,130) including at least one resistor (120) having an adjustable resistance; providing on the second surface (134) a pressure sensing integrated circuit (110) including a pressure sensitive element (140) and associated circuitry (110) for producing a pressure sensitive output signal; providing on the substrate at least one electrically conductive passage (122a,122b) for electrically interconnecting the thick film signal conditioning circuit and the associated circuitry; and enclosing the second surface (134) of the substrate by means of a ported housing (128) and substantially simultaneously sealing the or each electrically conductive passage so as to form a pressurisable chamber.

6. A method according to claim 5, wherein the or each electrically conductive passage is located adjacent a perimeter of the substrate.

7. A method according to claim 5 or 6, comprising the steps of pressurizing the chamber so as to cause the pressure sensitive integrated circuit and the signal conditioning circuit to produce an output signal; and adjusting the resistance of the or each resistor (120) disposed on the first surface in response to the output signal.

8. A method according to claim 7, comprising the step of enclosing the first surface of the substrate after adjustment of the or each resistor.

9. A method according to claim 8, wherein the substrate is enclosed in a manner as to make the pressure sensor air-tight.

10. A method according to claim 8 or 9, comprising the step of passivating the first surface of the substrate after adjustment of the or each resistor and before enclosing the first surface of the substrate.

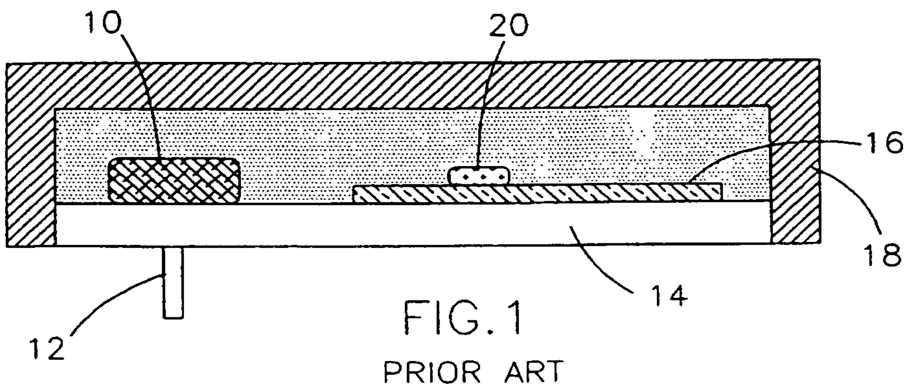

FIG. 1
PRIOR ART

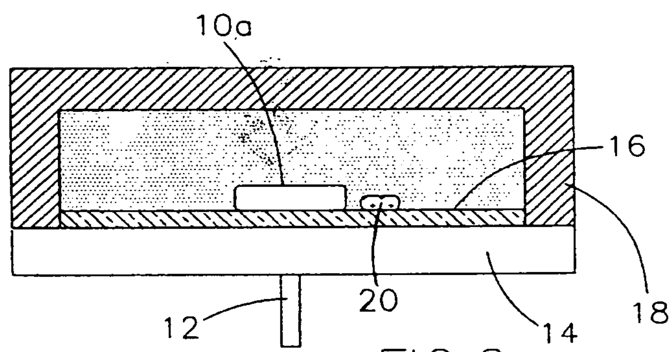

FIG. 2
PRIOR ART

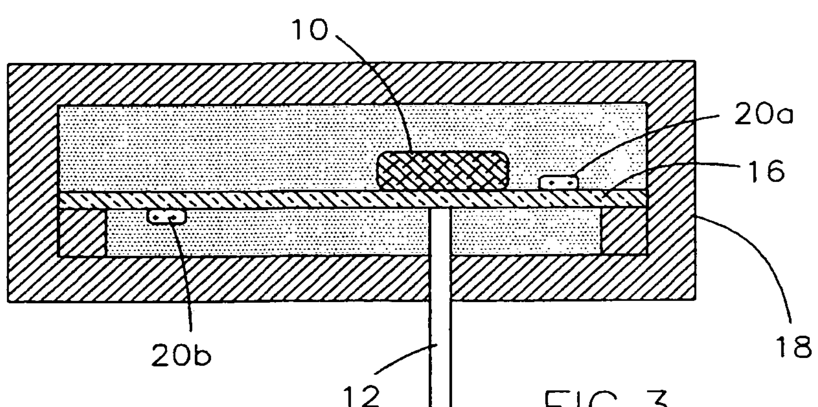

FIG. 3
PRIOR ART

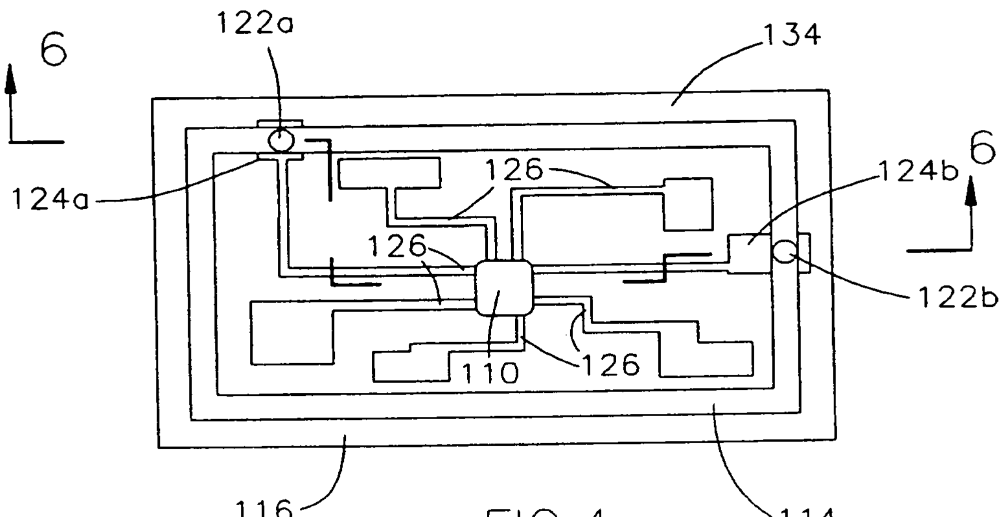
6
122a
134
124a
126
124b
6
126
122b
126
110
116
114

FIG.4

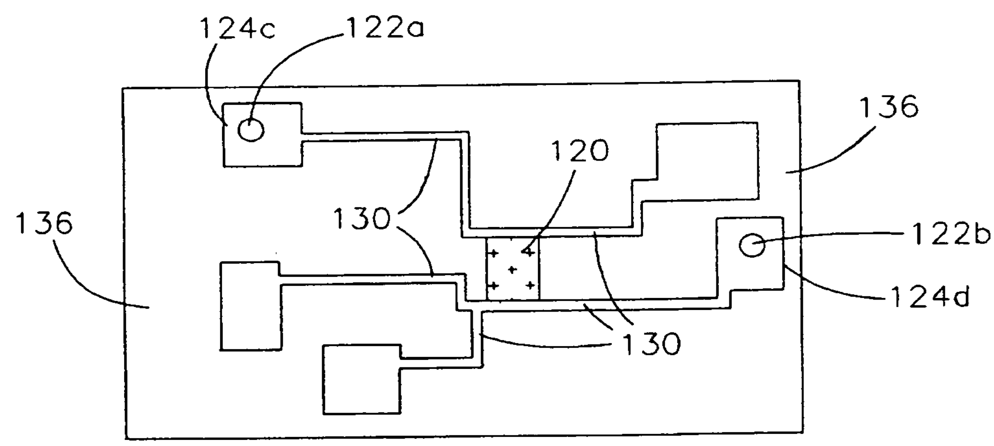
124c
122a
136
120
136
130
122b
124d
130

FIG.5

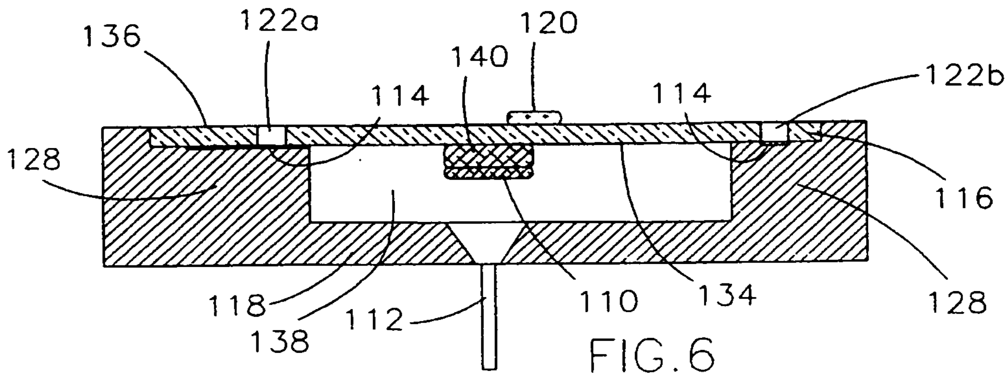
136
122a
120
140
114
114
122b
128
116
118
138
112
110
134
128

FIG. 6

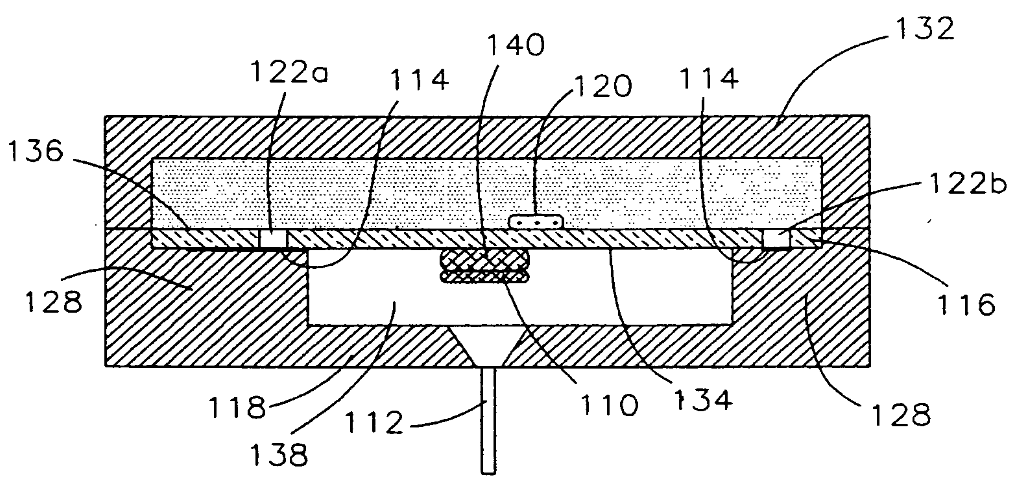
132
140
122a
114
120
114
136
122b
128
116
118
112
110
134
128
138

FIG. 7